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Modelling and Observations of the Equatorial Ionosphere

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The equatorial ionosphere experiences one of the most severe forms of a geophysical plasma instability - a phenomenon known as spread-F. An observational campaign was organized to bring a complement of diagnostic instruments to two sites in the western Pacific sector (Kwajalein Atoll in the Marshall Islands and Wake Island) for a period of coordinated optical and radio measurements of spread-F phenemona in August 1988. All-sky optical imaging observations were conducted from 2-16 August in conjunction with ALTAIR radar observations on Kwajalein. Preliminary review of the data sets obtained identified at least five case study events for detailed investigation.

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I. INTRODUCTION.

I.1. Background. During the period 1 October 1987 to 30 September 1988 (FY88), research efforts under AFGL Contract # F19628-86-K-0026 dealt with several topics concerned with ionospheric dynamics at low and equatorial latitudes. Some of these areas represent on-going work and will be reviewed here only briefly. The main effort of the year centered on the organization and implementation of a major field campaign. The scientific objectives and observational approaches used in this campaign will form the basis of our FY88 Annual Report.

I.2. On-Going Program. FY88 Quarterly reports described work on ionospheric storms initiated during this period. Briefly, total electron content (TEC) data taken at the AFGL sites in Ramey, PR, and the Kennedy Space Center (KSC), FL, were examined for "twin peak" enhancement effects on the first day of an ionospheric storm. This work was motivated by the very dramatic cases of this effect observed at L=1.7 (KSC) and L=1.4 (Ramey) during the solar minimum storm period of February 1986. Graduate student Xiaoqing Pi developed various data display programs to document TEC behavior with respect to monthly mean patterns, and work continues in this area.

A second area of study dealt with 6300Å imaging data taken in Brazil. With support from AFGL, Boston University entered into a collaboration with the Institute for Space Physics (INPE) in Brazil that resulted in the loan of an imaging system to the INPE observatory in Chociera Paulista, near San Paolo. The Co-investigator for this work is Dr. Yogeshwa Sahai, an optical aeronomer and senior staff member at INPE. The site is near the southern intertropical arc, or southern crest of the equatorial anomaly, where airglow levels are high and are thus well-suited for detection of airglow depletions related to the equatorial bubbles or plumes of plasma depletions and irregularities associated with spread-F at low latitudes.

The first year of observations from Brazil were reviewed in Boston during a month long working visit in January 1988. Working with Dr. Sahai, several periods were selected for case studies and it was decided to continue with a second year of observations. Preliminary results from the INPE collaboration were described in several of our quarterly reports.

A third area of study involved the comparison of the AFGL/BU Semi-empirical Lowlatitude Ionospheric Model (SLIM) with airglow observations made at the INPE observatory. As described in our quarterly reports, the comparisons revealed periods of both excellent agreement and substantial difference. Follow-up studies involved normalization of the SLIM model to local foF2 data and recomputation of the 6300Å levels. These results are still under analysis and will form the basis of FY89 reports.

II. Project JOHANNA.

II.1.<u>Background.</u> The equatorial ionosphere presents one of the most challanging topics in space plasma physics in the phenomenon known as equatorial spread-F (ESF). Historically, the ESF label came from the observation that ionosondes near the geomagnetic equator reported reflections from the F-layer that were so spread in plasma frequency that no standard analysis technique could be used to derive the electron density profile under such conditions. Years of subsequent research revealed that this relatively obscure radio propagation effect actually signalled the occurrence of a dramatic plasma instability that produced the most severe electron density irregularities known in the ionosphere. Moreover, the fact that these effects spanned the geomagnetic equator from approximately $\pm$ 15° pointed to a plasma instability process that was the largest to occur in the upper atmosphere.

Over the past decade, numerical simulation models have been successful in demonstrating that the equatorial plasma depletions could result from a Rayleigh-Taylor-type instability that occurs in the hours immediately following sunset. Figures 1 and 2 give model results presented by Zalesak et al. (1982) and Cakir and Haerendel (1985). In each case, a small "seed bubble" or "ripple" is introduced into the bottomside F-region and the instabiltiy process in modelled for 30 to 90 minutes. The end result is a rising plume of irregularities that "percolates" up through the ionosphere, similar in many ways to what is observed.

During this same period of intensive modelling, several groups initiated field campaigns to document ESF phenomena seen in multi-diagnostic systems. Wide-angle airglow imaging was introduced by Weber et al. (1978) showing for the first time the large-scale context in which line-of-sight radio and in-situ plasma instruments sampled equatorial plumes. Mendillo, Spence and Zalesak (1985) confirmed the modelling results in 6300Å and 7774Å using observations taken during AFGL's BIME Campaign (Figure 3). While the AFGL and Boston University studies have addressed many of the characteristics of well-formed plumes, it still remains unclear what processes or mechanisms determine the

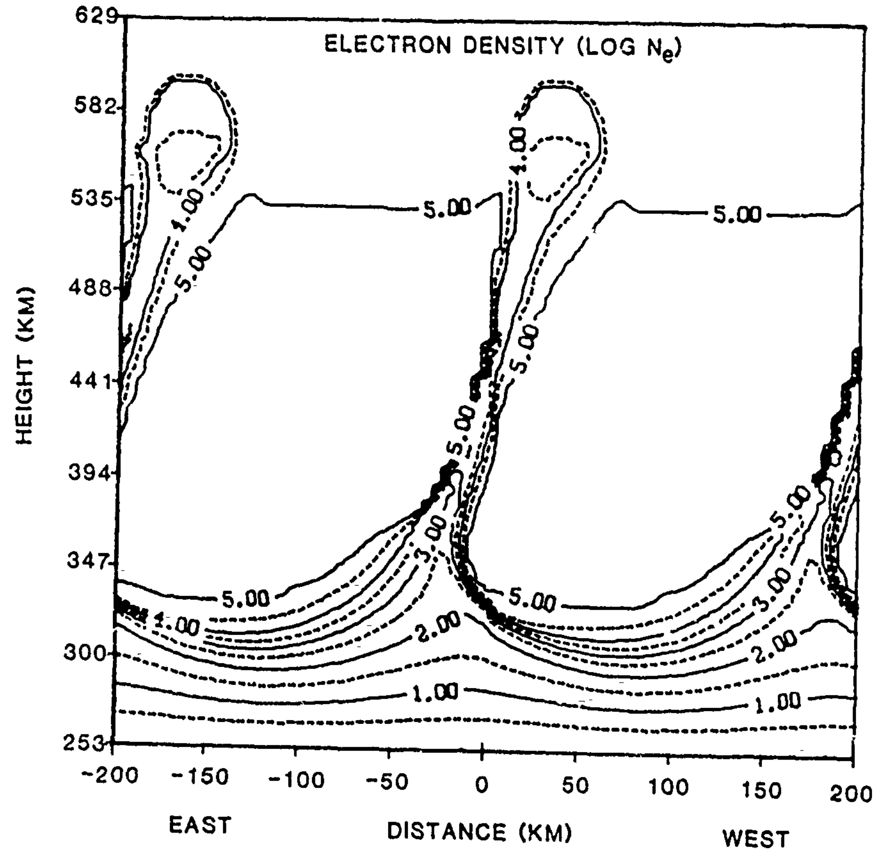

Figure 1. Contours of F-region electron density 39 minutes after the introduction of a wave-like disturbance into the bottomside of the profile (after Zalesak et al., 1982). Such simulation results address the instability processes thought to be responsible of equatorial spread-F (ESF).

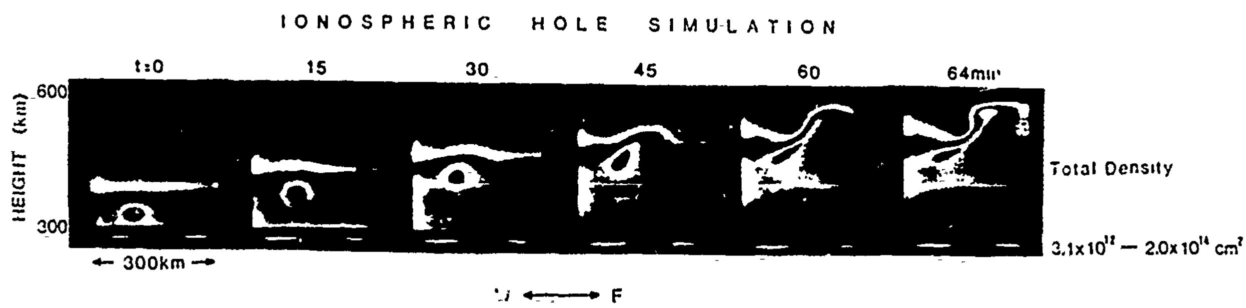

Figure 2. Evolution and structuring of an ionospheric hole introduced into the post-sunset equatorial ionosphere (after Cakin and Haerendel, 1984).

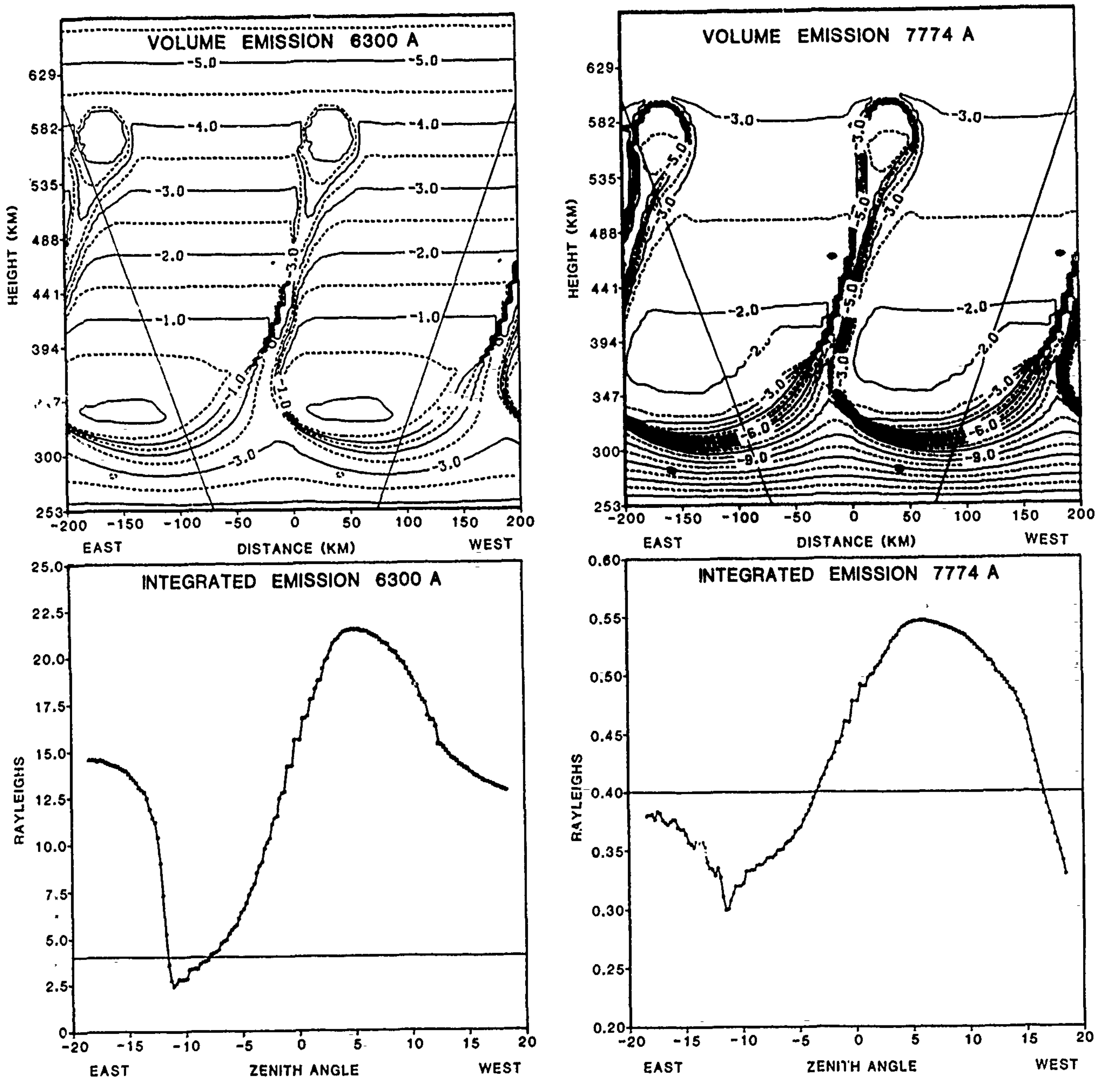

Figure 3. Simulation results for airglow signatures associated with the F-region depletion patterns derived by Zalesak et al. in Figure 1. Observations made in Brazil by the BIME campaign (September 1982) confirmed the pattern of strong enhancements in 6300Å predicted from the downward motion of plasma at the edges of the up-welling, motions (Mendillo et al., 1985).

day-to-day occurrence patterns of plumes. The onset criteria for the instabilty thus remain an area of intensive study, both observationally and in simulation work (Maruyama, 1988).

II.2. The Kwajalein Campaign of August 1988. One of the premier sites for equatorial studies is the installation operated by the U.S. Army on the Kwajalein Atoll (USAKA) in the Marshall Islands. Central to this facility in a 150-ft fully steerable radar (ALTAIR) that, in addition to its main task of traking space vehicles, can be used as an ionospheric diagnostic instrument. Two modes are possible, depending on the choice of viewing geometry. As an incoherent scatter radar (ISR), it measures electron density profies thereby determining ionospheric structure over a wide possibility of viewing directions. When directed to specific points where the ray path is perpendicular to the geomagnetic field lines at ionospheric altitudes, the radar becomes sensitive to a strong backscattered signal from F-region electron density irregularities present at those points. The weak ISR signals are overwhelmed under these conditions and thus $N_e(h)$ information is lost. However, in this backscatter radar (BSR) mode, ALTAIR can be used to map out irregularity patterns throughout the regions where perpendicularity is achieved. Taken together, the ISR and BSR data sets, available over broad regions, provide a unique diagnostic capability for equatorial aeronomy (Tsunoda, 1981).

II.2.1. PEAK Observing Program.

Under the sponsorship of DNA, a radio diagnostic study of "Propagation Effects Assessment at Kwajalein" (PEAK) was scheduled by SRI International and Mission Research for the period 2-31 August 1988. The aim of the PEAK program was to track satellites through equatorial depletions and document the degradation in signal experienced under such conditions. PI for the PEAK program at ALTAIR was Roland Tsunoda of SRI. Discussions with Tsunoda led to the suggestion that supporting diagnostics be deployed at or near Kwajalein to make multi-diagnostic observations of equatorial depletion effects. Interest is this work in central to the AFGL contract in ionospheric research at Boston University, as well as to ongoing plans for the NASA CRRES experiments scheduled for Kwajalein in Summer 1990.

II.2.2. NSF CEDAR Studies of Equatorial Dynamics.

Given the plans and interests described above, it was suggested to Dr. Tinsley of the NSF that a Workshop on Equatorial Dynamics be organized for the 4 -8 June 1988 Workshop in Boulder, CO, with the intent of defining a multi-year study of equatorial processes of interest to the CEDAR Program. The Workshop was co-chaired by M. Mendillo and B. Tinsley and attracted over 40 participants. Presentations were made by Tsunoda, as well as several potential participants, including E. Weber and Santimay Basu from AFGL. It was decided to define the optical observing period within the PEAK window (2-15 August) as the first in a series of equatorial campaigns to fall under the CEDAR sponsorship. At the suggestion of M. Mendillo, the 1988 campaign was called "Joint Observations of the High Altitude Non-Neutral Atmosphere (JOHANNA)".

II.3. Logistical Support.

The rapid organizational time associated with the JOHANNA campaign required experienced field support to make it a reality. We are pleased to acknowledge the very significant efforts made by Dr. Weber, Dr. Basu and the AFGL Logistics Office in assisting Boston University in these matters. Our Mobile Ionospheric Observatory (MIO) was certified for air transport and all personnel travel and housing arrangements were made through AFGL.

In order to have observations along the geomagnetic field lines that pass over Kwajalein (where the ALTAIR radar would be making PEAK measurements), it was decided to send teams to both the Kwajalein Atoll and Wake Island (600 miles north of Kwajalein). The MIO was shipped to Wake via MAC, and Boston University team members (Staff Scientist J. Baumgardner and graduate student R. Doe) went to Wake in late July to set up the MIO all-sky imaging system. Several days later, graduate student Peter Sultan went to Wake and Baumgardner returned to Kwajalein to set up a second all-sky system on Roi-Namur which he operated with M. Mendillo.

An AFGL narrow field imager was also set up on Wake Island and operated by AFGL personnel. On Kwajalein, several radio and satellite monitoring systems were established in the same trailer that housed the BU optical system. These efforts were under the overall direction of Dr. Basu, but involved colleagues from other branches and groups working at AFGL.

In summary, a complex set of logistical matters were handled efficiently and all systems were made operational by 2 August. There was some major damage to equipment experienced during shipping, but in-field repairs were made and no significant amount of data were lost to shipping problems.

III. SUMMARY OF OBSERVATIONS

III.1. Data Availability.

The log kept of the nightly observations taken during the JOHANNA campaign is reproduced in the Appendix. Given that this program ended barely a month prior to the FY88 reporting period covered by this report, only a preliminary catalog of the data is available. As can be seen from the Appendix, observations were made on 15 nights, with many periods of joint observations with ALTAIR. Efforts were also made to operate during periods when the HILAT, Polar BEAR and San Marco satellites passes the Kwajalein meridian. Weather conditions were generally very favorable at both Kwajalein and Wake, and thus good optical coverage was obtained.

As part of the CEDAR effort, imaging systems were operated at two additional longitudes from the Wake-Kwajalein meridian documented in Table A. At Mt. Haleakala, Hawaii, a team from the University of Texas, Dallas, operated a Monochromatic Imaging Photometer (MIP) during the period 5-17 August 1988. The observers were R. Rohrbaugh, W. Hanson and E. Anderson, and observations were conducted at 6300Å, 7774Å, and 5577Å.

A third longitude site was at the INPE observatory in C. Paulista in Brazil. Boston University's film-based intensified imager on loan to INPE was operated in all-sky mode at 6300Å during the period 7-19 August 1988. The observer was Y. Sahai.

III.2. Case Studies.

A comparison of the ALTAIR radar data, satellite radio beacon data and imaging data taken on Kwajalein and Wake led to an initial choice of five (5) events for detailed analyses. These are:

(1) 7 August, 11:00-12:30 UT

(2) 9 August, 9:30-14:00 UT

(3) 10 August, 9:00-12:00 UT

(4) 12 August, 8:30- 9:30 UT

(5) 15 August, 8:00- 9:30 UT

Of these five cases, three (#1,2,4) represent periods of clear skies at the Hawaian and Brazilian longitudes. Thus it was decided to concentrate on these three periods for initial analysis. We anticipate presenting results from these events at the CEDAR Workshop scheduled for June 1989 in Boulder.

IV. ACKNOWLEDGEMENTS

The work conducted under this contract as reported in various sections of this report was carried out in conjunction with J. Baumgardner, J. Aarons, X.-Q. Pi, R. Doe and P. Sultan at Boston University, D. Anderson, J. Klobuchar, E. Weber and S. Basu at AFGL, and Y. Sahai at INPE, Brazil. Their dedication and cooperation was very much appreciated.

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Tsunoda, R., Time evolution and dynamics of equatorial backscatter plumes, 1. growth phase, J. Geophys. Res., 86, 139, 1981.

Weber, E., J. Buchau, R. Eather, and S. Mende, North-south aligned equatorial airglow depletions, J. Geophus. Res., 83, 712, 1978.

Zalesak, S., S. Ossakow, and P. Chaturvedi, Nonlinear equatorial spread F: the effect of neutral winds and background Pederson conductivity, J. Geophys. Res., 87, 151, 1982.

VI. APPENDIX

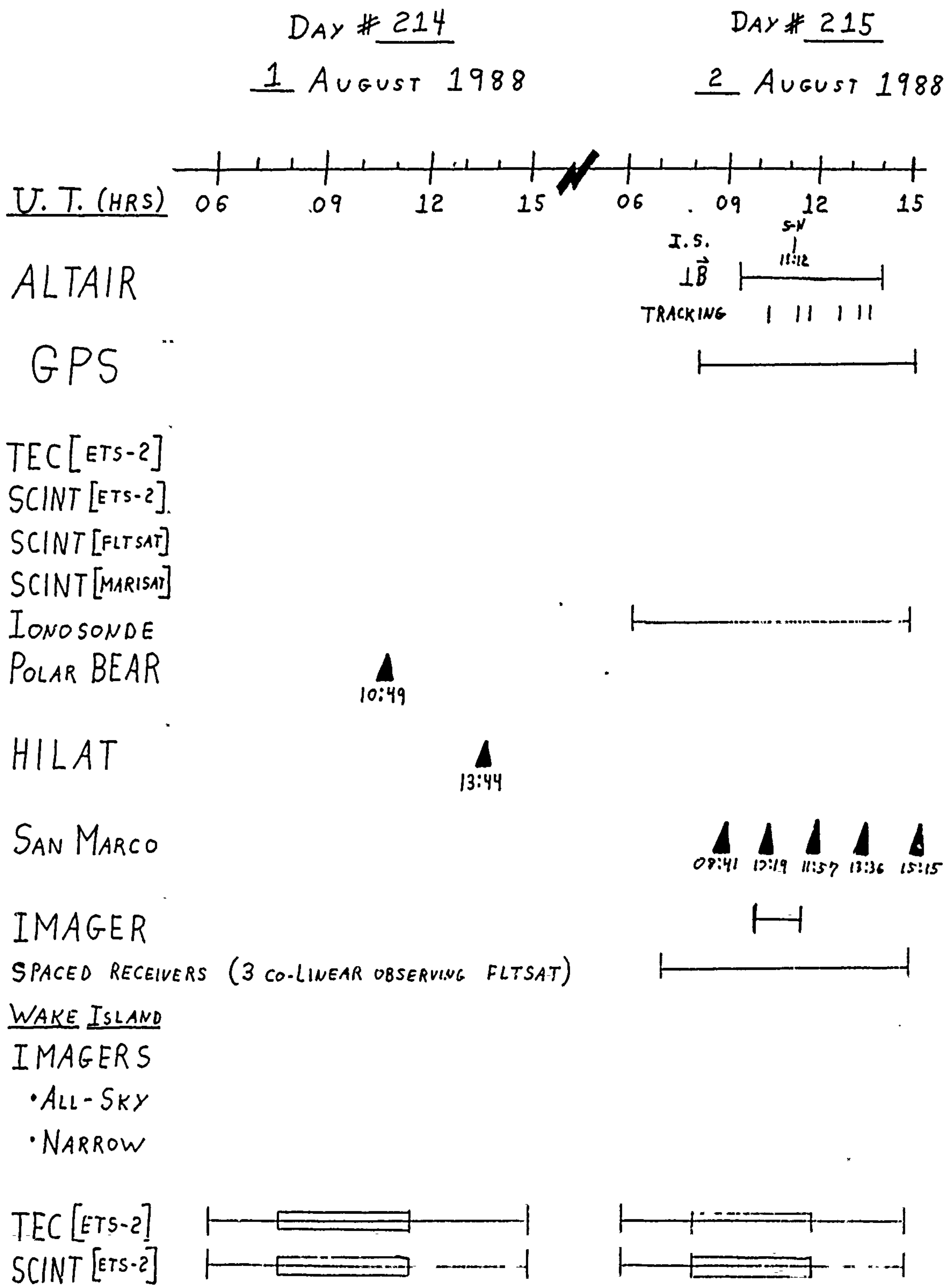
Observations of log coordinated radar, ionosonde optical and radio beacon systems operating on Roi-Namur (Kwajalein Atoll) and on Wake Island.

KWAJALEIN — 1988
• PEAK PROGRAM – 2 - 31 August
• JOHANNA CAMPAIGN – 2 - 16 August

— Summary of Joint Observation Schedules During "Johanna Period"

Notes:

- All times and dates in UT (= GMT = Zulu)
- Log notes cover UT interval 06:00 – 15:00 U.T.
  (but some systems observed longer or full 24-hrs)
- For satellite Radio Beacon (SRB) Observations, periods of high time resolution are noted by double lines
- For satellite passes (Polar BEAR, HILAT, San Marco) times quoted are for start-times of passes
- ALTAIR start/end period actually contains three modes
  (1) Backscatter (⊥B) scans, (2) Incoherent Scatter scans, (3) Sat. Tracking
  - Times for each scan TBD
- Imager data contain multi-wavelength and background pictures.
  - Times for each image TBD
  - Periods of partial clouds not noted, i.e., total periods plotted.
- Send Additions/Corrections to M. Mendillo (617)353-2629, Center for Space Physics, 725 Commonwealth Avenue, Boston, MA 02215, SPAN = BUASTA::MENDILLO



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DAY # 215
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SCINT [MARISAT]
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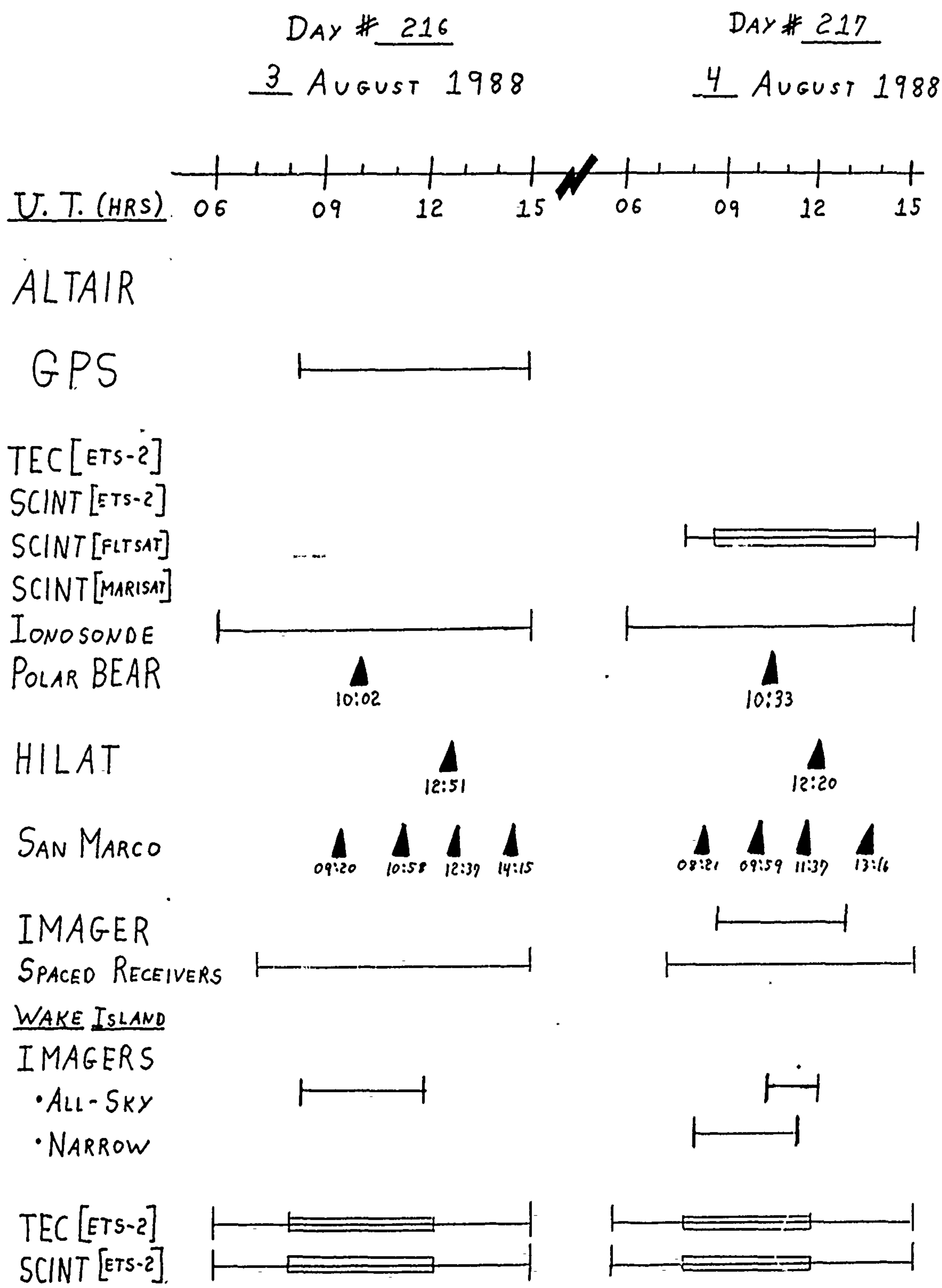
SCINT [ETS-2]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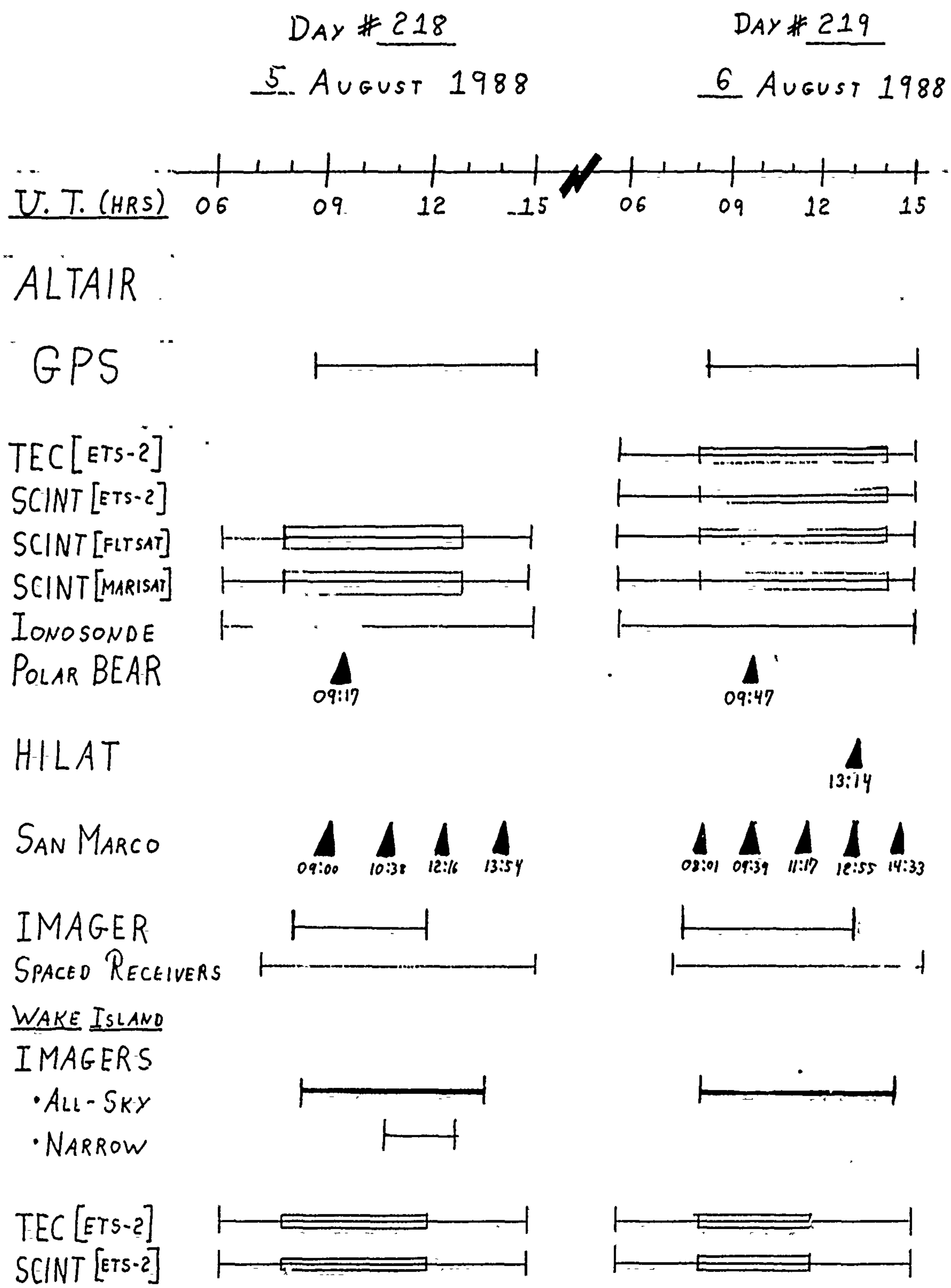
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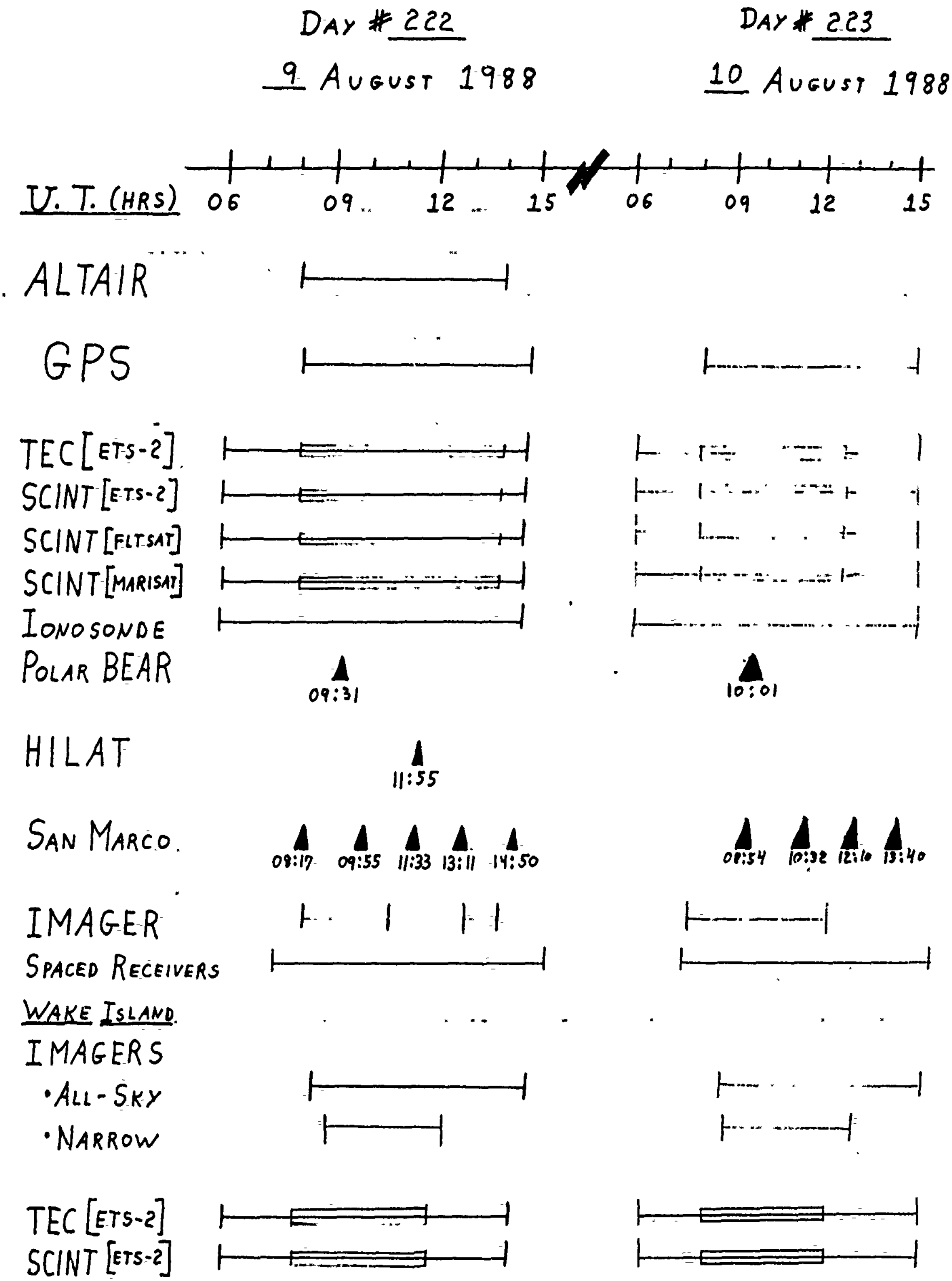
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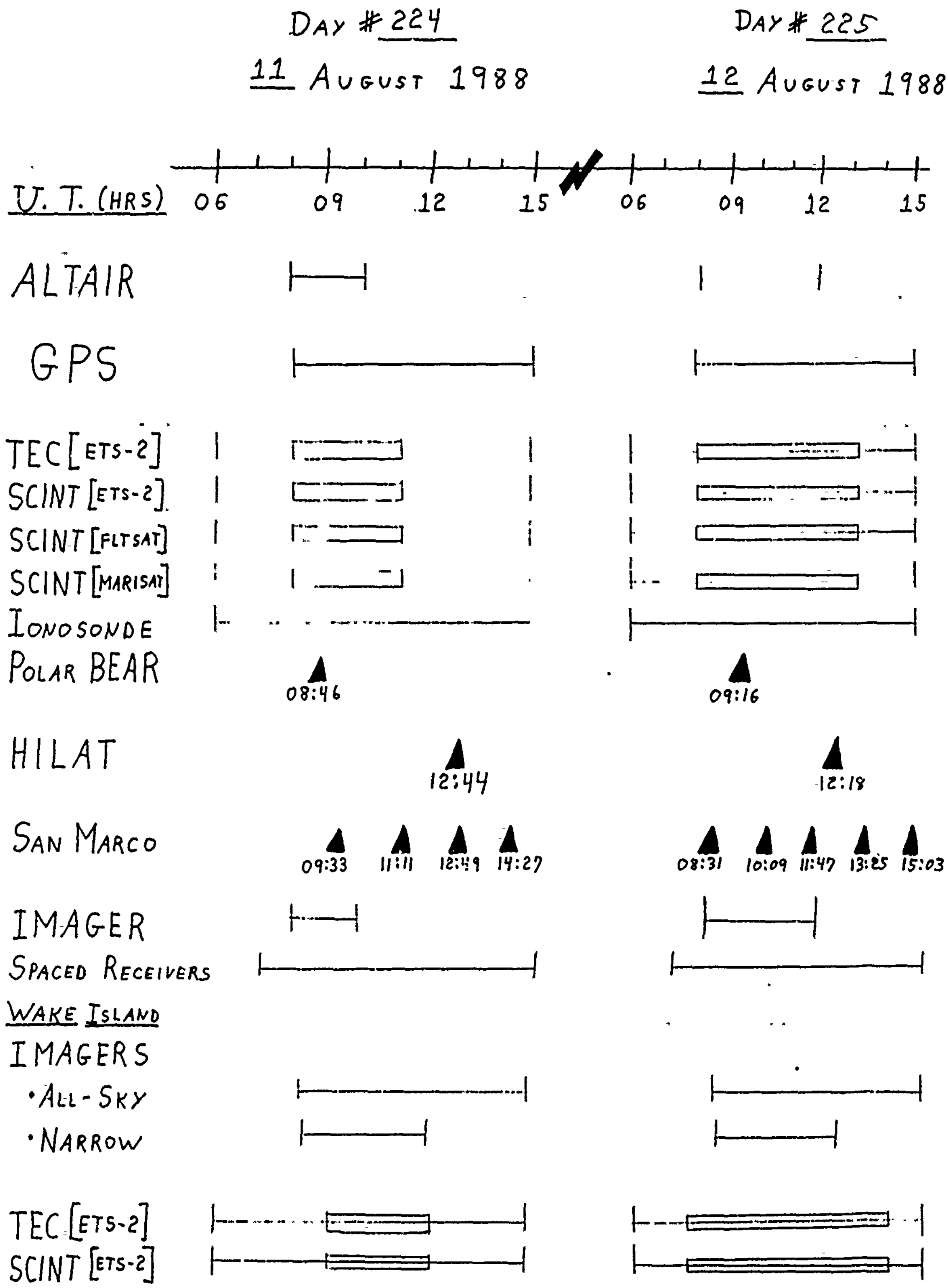
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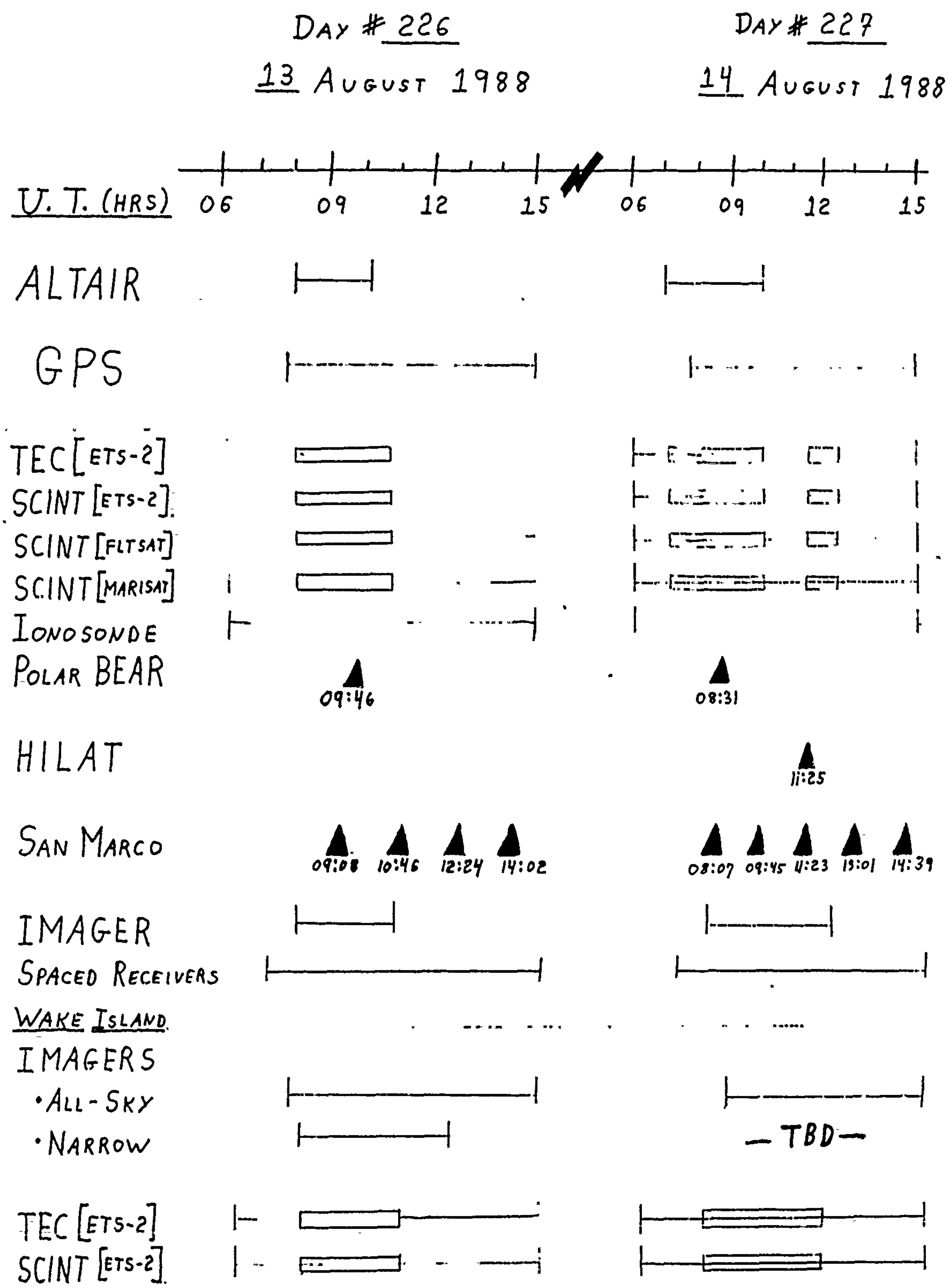
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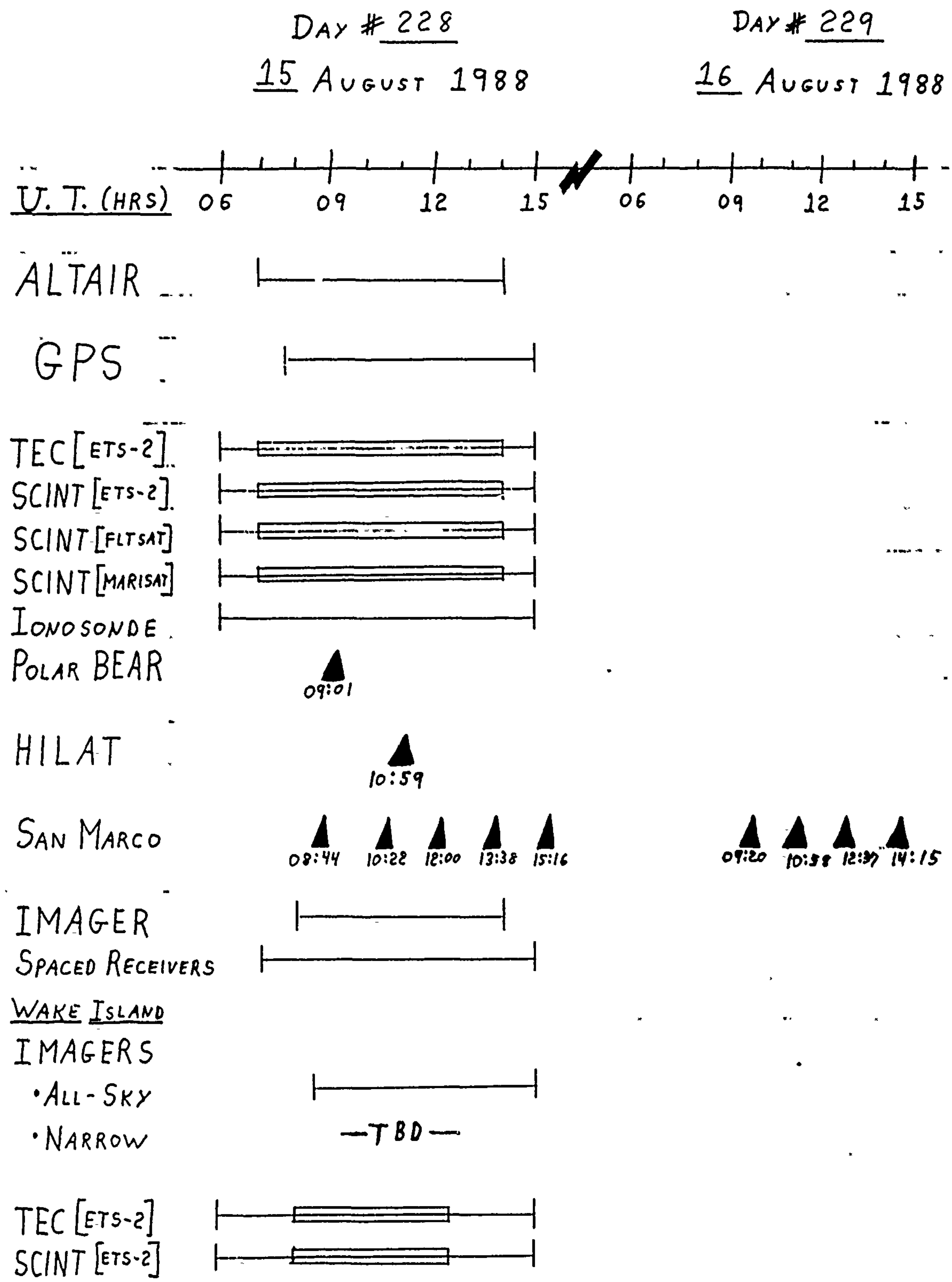
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